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ENGINEERING REPORT

SECURITY INFORMATION

REPORT NO: 172-D **DATE.** 11/15/52

TITLE: DEVELOPMENT OF HIGH PERFORMANCE ROTARY WING, TIP-MOUNTED PULSE-JET ENGINE COMPONENTS

FOURTH QUARTERLY PROGRESS REPORT

MODEL NO. **COPY NO.** 38

CONTRACT NO. AF 33(600)-5860
Expenditure Order No. X 506-230

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1. SUMMARY

This report describes the work which has been accomplished in the development of rotary wing tip-mounted pulse-jet engines under U. S. Air Forces Contract No. AF 33(600)-5860 during the period from July 15, 1952 to October 15, 1952.

The effect of a 35% increase in cooling air inlet duct area has been to increase the structural strength of the Conical engines.

Aluminum has been considered and proven inadequate for fabrication of the cooling air baffle.

The XPJ-49-AH-1 (AJ-7.5) inlet valve which was used in the 25 hour qualification test has been further tested to 38 hours without failure.

The fabrication of the valve tensiometer has been completed and a calibration of the spring elements has been accomplished.

A set of lower frequency reeds and a multiple point fuel injection system have been designed and fabricated for the 10.0 inch diameter engine.

The thrust performance of four cowling configurations has been evaluated and the high speed superiority of the short-lip circular type proven.

Three designs of 6.75 inch diameter development engines, as well as the XPJ-43-AH-1 (AJ-9.4) and XPJ-49-AH-1 (AJ-7.5) engines have been tested at high tip speeds on the recently completed Special Low "G" Test Stand. The XPJ-43-AH-1 engine was tested to 450 ft/sec. and the smaller engines were tested to 550 ft/sec.

The altitude effect on cowling parameters, inlet valve parameters, venturi parameters and tube geometry has been investigated.

As of 15 October 1952 the funds and man hours were 95% and 98%, respectively of the total contract.

2. INTRODUCTION

This is the fourth (quarterly) progress report to be submitted in accordance with Item 2a of Exhibit "A" of U.S. Air Forces Contract No. AF 33(600)-5860. Progress made in the development of improved tip-mounted pulse-jet engine components for rotary wing applications during the period of 15 July 1952 to 15 October 1952 is described herein. This development work is being accomplished in accordance with Item 1 of Exhibit "A" of the above mentioned Contract.

The information presented herein is intended to summarize the accomplishments during the period covered by this report. It should be noted that this report does not include work being accomplished under Supplement No. 4 to this contract. Work under the Supplement will be reported in a separate report.

The basic power plant development work has been accomplished by the Power Plant Division at the Mesa, Arizona facility and flight testing is being performed at the Manhattan Beach, California plant.

3. DISCUSSION

3.1 STRUCTURAL DEVELOPMENT

3.1.1 Work Accomplished

The engine shell temperature investigations have shown that the cooling air baffle is very effective in reducing the temperature of the tailpipe. The temperature of the baffle itself was indicated to be close to the softening temperature for aluminum (Reference 1). Since the baffle is not a load carrying member, it was decided to investigate the possibility of using this lightweight material. A one inch, aluminum extension was made to the stainless steel cooling baffle of an experimental engine.

This engine was used in the altitude test program and was operated at several tip speeds and all operable fuel rates at each altitude. At the conclusion of the test program the baffle extension was inspected. The "G" load and heat had deformed the inboard side of the extension and it had melted against the tailpipe. The outboard side of the aluminum extension, which could not come in contact with the tailpipe, was also warped. It has, therefore, been concluded that aluminum is inadequate for fabrication of the cooling air baffle; however, titanium, which is half as heavy as stainless steel, might be used.

The previous structural work, which was reported in References 1 and 2, has indicated that the tailpipe temperatures could be further reduced and the structure improved by increasing the amount of cooling air supplied to the tailpipe area. Therefore, a 35% increase in cooling air inlet scoop area was incorporated in experimental engines AJ-6.75-152, AJ-6.75-153, and AJ-6.75-154, shown in figure 1. These three engines have been tested at various speeds and subjected to centrifugal forces up to 300 "G". Each engine has accumulated between 3 and 4 hours of "hot time" during the altitude test program.

Careful inspection after completion of the altitude whirl test program has shown that none of the tailpipes have begun to ovalize or buckle. The usual failure of this type of engine consists of local buckling and collapse of the inboard side of the tailpipe. It is believed that the additional cooling air has prevented this failure.

The outer shell of one of the engines, AJ-6.75-152, started to buckle (between the two outboard cooling ports) during the first run. However, no further deformation occurred in any of the subsequent runs. This partial failure pointed out the importance of locating the inlet air ports away from the part of the shell where maximum compressive buckling stress occurs.

3.1.2 Work to Be Accomplished

The summary report of structural development work will be completed during the forthcoming quarter.

3.2 INLET VALVE DEVELOPMENT

3.2.1 Work Accomplished

As was previously reported (Reference 1), the 6.75" diameter engine valve box, which was being life tested had accumulated 60 hours and was still in good operating condition. Since the engine tube, at the present time, under high "G" loads has a life expectancy of about 35 hours, it was deemed inadvisable to further extend the valve life test evaluation at this time. However, the 7.5" diameter engine valve which was used in the Flight Rating Test, Reference 3, was further tested to determine its life expectancy.

This test was conducted on the 167 inch radius whirl arm on the Endurance Test Stand. After a total time of 38 hours had been accumulated, the whirl stand tie-down bolts failed due to fatigue and the tripod broke loose from the moorings and damaged the whirl arm and the engine was completely demolished. The valve box had been inspected after 36½ hours and was in very good condition at that time. The valve life is believed to be considerably greater than 38 hours.

The fabrication of the valve tensiometer has been completed and the spring elements calibrated. The valve tensiometer was designed to test the stiffness of reed assemblies and find the over all spring constant of the reed and keeper assembly. This unit is shown in figure 2. The force is applied through the calibrated center spring by turning the wing nuts on either side. The deflection of the reed assembly is read on the dial gage.

3.2.2 Work to be Accomplished

The tensiometer measurements and the effect of valve tension on engine performance will be investigated in conjunction with work under Supplement No. 4 to the subject contract.

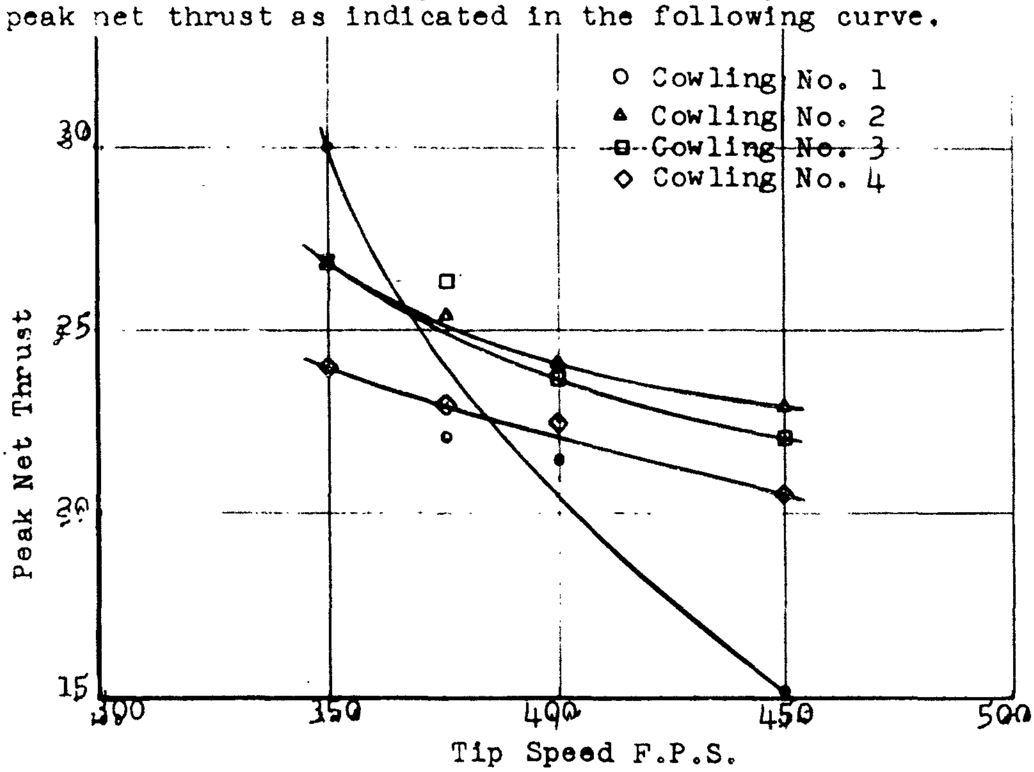
The summary report covering the work accomplished under this phase of the original contract will be prepared.

3.3 HIGH SPEED PERFORMANCE IMPROVEMENT

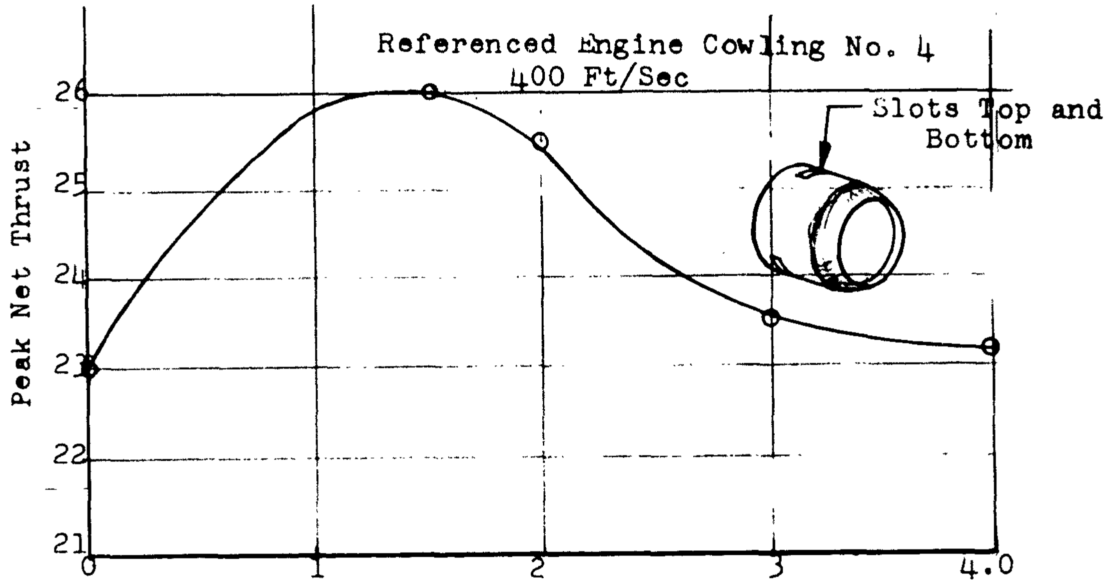
3.3.1 Work Accomplished

Four designs of inlet cowling have been investigated to determine their drag and their effect on the thrust performance of a 6.75" diameter engine. A description of the cowls and the cold drag performance is presented in Reference 1. A picture of the cowls is reprinted herein as figure 3 for convenient reference. The cowling tests were made with a 6.75" diameter "reference" engine (AJ-6.75-140) mounted on a 225" radius whirl arm. Performance whirl tests were made at tip velocitiesof 350, 375, 400, and 450 ft/sec.

Each cowl was evaluated with this constant engine configuration. Cowlings 2 and 3 (figure 3) produced the highest net thrust and had almost the same performance at 350 ft/sec. tip velocity where cowl No. 1 produced the highest peak net thrust as indicated in the following curve.



The effect of air bleed-off on engine performance at 400 ft/sec. with cowling No. 4 is shown in the following curve:



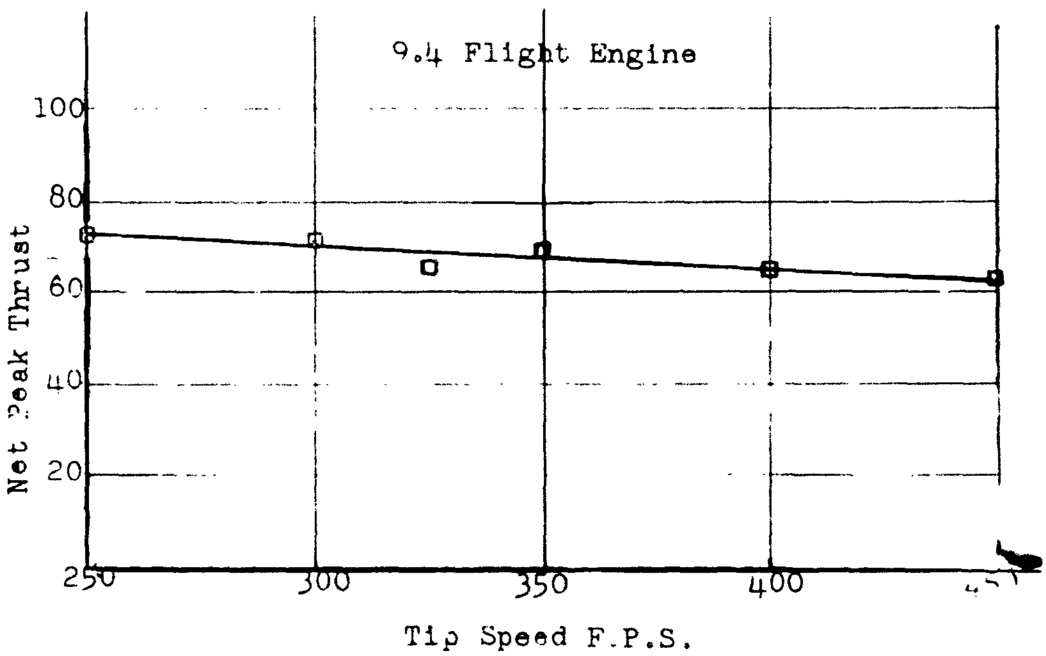
These data indicate that the thrust performance can be increased with air bleed-off in a diffusion type cowling and the optimum bleed-off area for cowling No. 4 is a 3/8" x 2" slot located at the top and bottom of the cowl directly aft of the valve box face.

From the foregoing data, it is concluded that the NACA series 1 circular type cowling is superior to the original rectangular ram type cowling; especially at tip velocities above 350 ft/sec. Cowling No. 2 and cowling No. 3 were found to offer the lowest cold drag and gave the highest thrust performance of all the cowls over the range of tip velocities that were covered. Air bleed-off did improve the performance of the diffusion-cowl (No.4)and thus improved performance decreased as the air bleed slot was progressively increased in size.

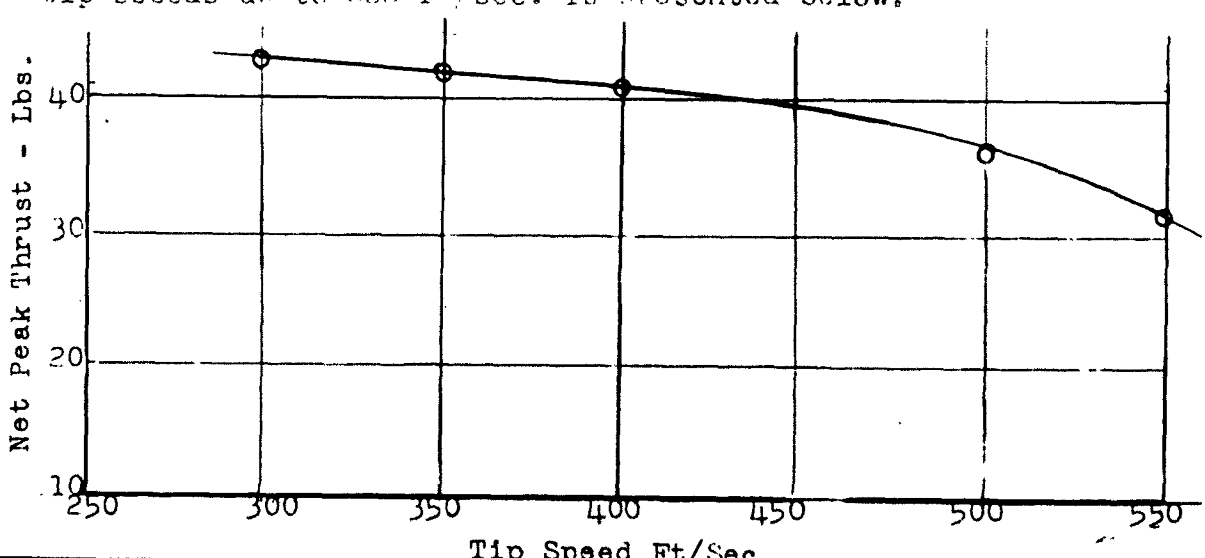
An alternate, multiple point, fuel injection system has been designed for the 10.0" diameter engines in order to improve the distribution and atomization of the fuel. This is essentially a center-located cluster nozzle design.

The valve natural frequency investigations reported in Reference 1 have indicated that the engine performance is optimum when the natural frequency of the reeds is close to the frequency of the engine tube. The original 10.0" diameter engine reed design had a natural frequency of 160 cps. Since the frequency of the 10.0" diameter engine is 110 cps, alternate reeds were designed for a frequency in the same range as the engine.

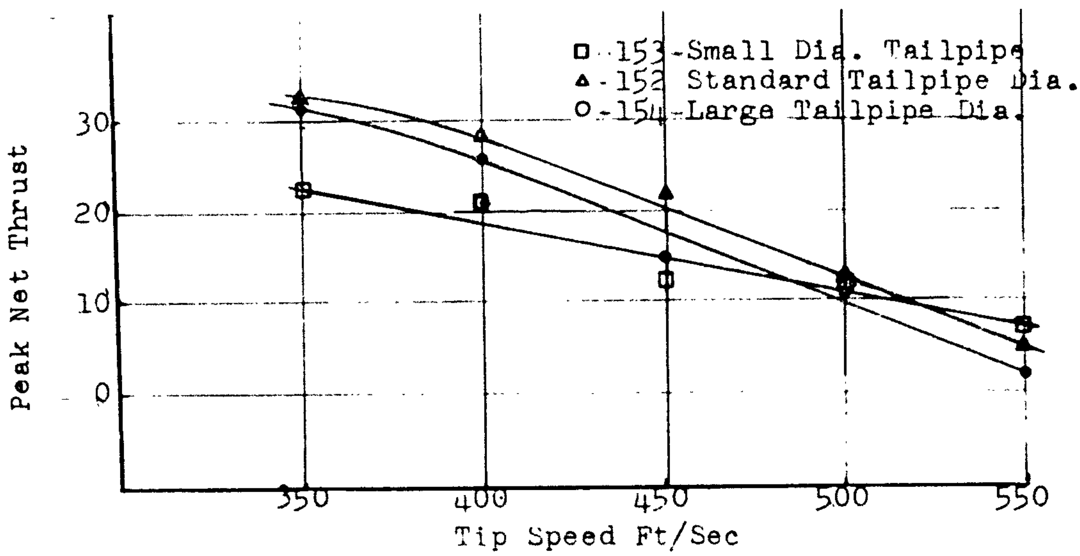
Since the completion of the Special Test Stand (Low "G") the performance data on most of the basic engine designs has been extended to the higher tip speeds. The XPJ-43-AH-1 (AJ-9.4) engine data, which were previously limited to a maximum speed of 350 ft/sec, have now been extended to tip speeds of 400 and 450 ft/sec. Engine performance was as follows:



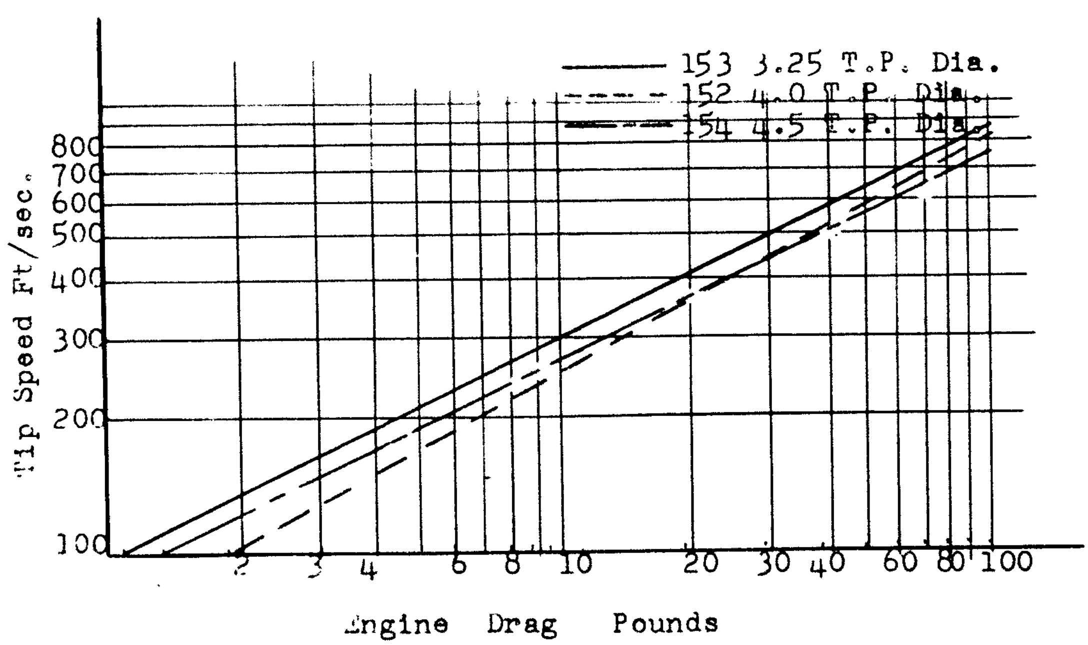
The performance for the XPJ-43-AH-1 (AJ-7.5) engine at tip speeds up to 550 ft/sec. is presented below.



Three designs of 6.75" diameter experimental engines have also been tested at higher tip speeds. The high speed data for these test engines is presented in the figure below. The principal difference between these engines is the diameter of the tailpipe as indicated in figure 1.



The effect of tailpipe diameter on the engine cold drag is presented in the curve below and helps to explain the superior performance of the small tailpipe engine at 550 ft/sec.



3.3.2 Work to be Accomplished

The summary report covering this phase of the development program will be prepared.

3.4 ALTITUDE WHIRL TESTING

3.4.1 Work Accomplished

An intensive altitude development whirl test program has been carried out during the present report period. Tests were made at equivalent standard density altitudes of 12,300, 10,300, 8,000, and 3,000 feet. The effects of inlet cowling design, valve open area, venturi throat area and tailpipe area were evaluated at various altitudes.

The data and subject matter are extensive enough to warrant presentation in a separate report. This report is presently being prepared.

3.4.2 Work to be Accomplished

The report of altitude test results will be completed. These results will also be presented in the summary report.

3.5 FUNCTIONAL AND MAINTENANCE INVESTIGATIONS

The remaining items of work to be completed under the Functional and Maintenance Investigation phase is a thermodynamic analysis to determine the feasibility of using the heat evolved from the cooling of the pulse-jet engine for helicopter rotor blade deicing.

Because of the heavy work load in the Analytical Group, it has been necessary to postpone the rotor deicing analysis until December. This analysis will be subject of a separate report. The results will also be incorporated in the summary report.

4. CONCLUSIONS

The major accomplishments under Contract No. AF 33(600-5860 during the period covered by this report were:

a) Whirl test evaluation of engines providing for 34% more tailpipe cooling air than previous configurations.
b) Life tests to 38 hours on a valve box assembly from the XPJ-49-AH-1 (AJ-7.5) engine without failure of the valves.
c) The valve tensiometer was completed and calibrated.
d) Tests of four different inlet cowl configurations were completed.
e) Alternate fuel injector and valve configurations for the 10.0" diameter engine were designed and fabricated.
f) Tests of various engines to 550 ft/sec. tip speed were accomplished on the new, Special Test Stand.
g) A report covering the results of the altitude whirl test program is being prepared.

Work will be initiated on the summary report(s) covering all of the work accomplished under the various phases of this contract during the forthcoming quarter. The summary report(s) will fulfill the contractual requirement of Item 2c of Exhibit "A" of the original contract (this does not include work under Supplement No. 4 of this contract).

As of 15 October 1952, the funds and man-hours expended on this contract were 95% and 98% respectively, of the total estimated cost and allotted hours.

5. REFERENCES

Reference 1: American Helicopter Co., Inc. Report No. 172-C, "Development of High Performance Rotary Wing Tip-Mounted Pulse-Jet Engine Components - Third Quarterly Progress Report"

Reference 2: American Helicopter Co., Inc. Report No. 172-B, "Development of High Performance Rotary Wing Tip-Mounted Pulse-Jet Engine Components - Second Quarterly Progress Report"

Reference 3: American Helicopter Co., Inc. Report No. 157-L-3, "Results of Preliminary Flight Rating Tests of the Model AJ-7.5 Pulse-Jet Engine"

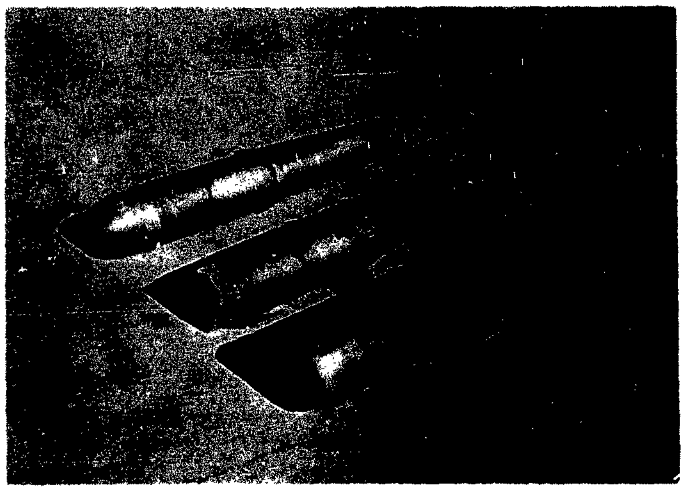


Figure 1

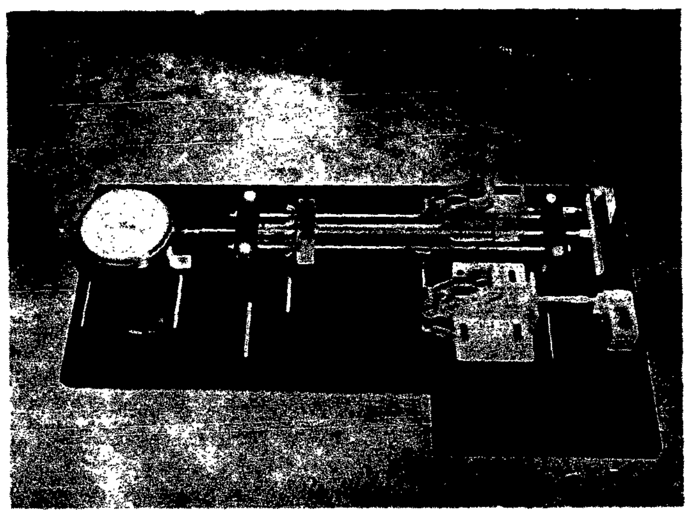


Figure 2

Figure 3